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Child Mortality in Rural India

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Abstract

This paper focuses on infant and child mortality in rural areas of India. We construct a flexible duration model framework, which allows for frailty at multiple levels and interactions between the child's age and individual, socio-economic and environmental characteristics. The model is estimated using the 1998/1999 wave of the Indian National Family and Health Survey. The estimation results show that socio-economic and environmental characteristics have significantly different impacts on mortality rates at different ages. These are particularly important immediately after birth. We use the estimated model for policy experiments. These indicate that child mortality can be reduced substantially, particularly by improving the education of women and reducing indoor air pollution caused by cooking fuels. In addition, providing access to electricity and sanitation facilities can reduce under-five-years mortality rates significantly.

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1 Introduction

Reducing child mortality should be placed on the top policy priority in India. In 1999, while the total under-five child deaths among less developed countries amounted to about 10 million, India alone accounted for about one-fifth of the under-five deaths (2.1 million), the highest number within a single country (Cleason, Bos and Pathmanathan, 1999). Not only in absolute numbers is child death high in India, but also child mortality rates are substantially higher than in other low-income countries. In 1999 the under-five-years mortality rate (U5MR) in India was 90 (per 1,000 live births), while the U5MR for China, Brazil and Indonesia in the same year was 37, 40, and 51, respectively.

Within India, there are large variations in child mortality rates across states as well as between urban and rural areas within individual states. The U5MR in 1995-99 (estimated using the 1998/99 National Family Health Survey, NFHS) ranged from 18 in Kerala to 137 in Madhya Pradesh. During the same period the U5MR in rural India was 111, which was nearly twice as high as in urban areas (65 per 1,000 live births).

Not only is the initial child mortality rate high, but also the decline in child mortality in India has been slow. During the 1990s, the infant mortality rate decreased from 80 to 70. Several states with substantially higher child mortality in the early 1990s, such as Rajasthan, Madhya Pradesh, Uttar Pradesh and Bihar, saw little decline in mortality at the end of the 1990s.

There exists a large body of empirical studies which focus on analyzing the determinants of child mortality in India.[1] The key findings often indicate that household income, female education, access to health services, and immunization programs are important determinants of child mortality. Several studies also identify a strong interrelationship between mortality, fertility and gender bias. This evidence indicates that public policies emphasizing on improving access to health services, and in particular on improving female literacy and socio-economic participation, can play an important role in reducing child mortality. Several recent studies have also shown that environmental conditions, such as access to safe water and sanitation facilities, access to electricity, and use of clean cooking fuels, have an important health impact among young children (Pandey, Cheo, Luther, Sahu and Chand, 1998; Hughes, Lvovsky and Dunleavy, 2001; Jalan and Ravallion, 2003; and Mishra and Retherford, 1997).

[1]Pandey, Cheo, Luther, Sahu and Chand (1998), Rosenzweig and Schultz (1982), Murthi, Guio and Dreze (1995) and Gleason (2003).

In this paper we use a duration model framework to analyze the determinants of child mortality, focusing particularly on household environmental conditions. There exist several theoretical frameworks in the field of child mortality analysis (see for a survey Wolpin, 1997), but duration models have several advantages over the alternatives. First, duration models can directly deal with such data problems as right-censoring, which is a major concern in analyzing child mortality risks. Second, child mortality risk often depends on many characteristics of the child, the household and the village, and the impact of these covariates on child mortality is likely to vary with the age of children. For example, Fikree, Il Azma and Berendes (2002) show that factors that affect neonatal deaths (in the first month before birth) are quite different from these for postnatal deaths. However, most empirical studies assume that these covariates have constant impacts on child mortality over the age of the child (e.g. Hughes, Lvovsky and Dunleavy, 2001; Guo and Rodriguez, 1992; Sastry, 1997; Ridder and Tunali, 1999). In contrast to the two studies on environmental health in India (Huges, Lvovsky and Dunleavy, 2001; and Jalan and Ravallion, 2003), we develop a duration model that incorporates age-varying covariate effects, i.e. it allows the impact of socio-economic and environmental characteristics to change with children's age. This modification is important as it allows us to identify the relevant health inputs at different ages of a child. The empirical results can thus provide critical information for quantifying the effectiveness of policy options for reducing child mortality through policy simulation.

Third, child mortality risks also depend on both observed health inputs and unobserved biological endowment or frailty. Not properly taking account of these unobserved characteristics or the relation between children within a family may lead to inconsistent and inefficient estimators. This issue is not only addressed in the economic literature (i.e. Ridder and Tunali, 1999), but also in other disciplines, including epidemiology and demography (Guo and Rodriguez, 1992; Sastry, 1997; Vaupel, Manton and Stallard, 1979). We allow for frailty on multiple levels (see Sastry, 1997). In particular, our model framework allows for frailty both at the level of the child and the level of the family (i.e. frailty similar for all children living in the same household). To distinguish these types of frailty we exploit the fact that children within the same family are related, which implies that they might share some unobserved characteristics. In contrast to Sastry (1997), our model specification does not impose the restriction that different types of frailty are independent of each other.

We estimate the model using data from the 1998/99 wave of the Indian National Family and Health Survey (NFHS). This is a rich, nationally representative database that covers around 90,000 households living in India. We use the estimated survival functions to perform simulations of policy experiments. In particular, we simulate how interventions that improve socio-economic and environmental characteristics of a family affect the survival probabilities of children at different ages. We examine the impacts of both single and combined policy interventions. Also we use the flexibility of our model framework to show at which age the interventions are most effective.

The paper is organized as follows. Section 2 summarizes the 1998/99 NFHS. Section 3 presents the statistical model. Estimation results are discussed in Section 4. In Section 5 we use the estimated model for performing policy simulations. Section 6 concludes.

2 Data

In this section we briefly summarize the data used in the empirical analyses. The data are from the second wave of the National Family and Health Survey (NFHS-2), undertaken in 1998 and 1999. The NFHS is conducted using the same survey design as the Demographic and Health Surveys (DHS) for more than 60 low-income countries since 1985. It provides information on fertility, mortality, health issues, socio-economic and environmental conditions. The NFHS covers a nationally representative sample in 26 states.[2] The response rate of the interviews was over 95%. The survey consists of 3 separate questionnaires, a village questionnaire, a household questionnaire, and a woman questionnaire covering all ever-married women in a household between age 15 and age 49.

The data set contains information on 92,486 households. Since we are interested in child mortality in the rural areas, we abstract all 61,800 households living in rural areas. As is often the case with data on child mortality, information on child mortality comes from surveys among women (e.g. Guo and Rodriguez, 1992).[3] The households living in the rural areas include 62,248 ever-married women between 15 and 49 years old who are interviewed. In the rural areas, more than 95% of the women between ages 25 and 30 have been married. As we are interested in recent birth histories, we restrict the sample to women below

[2] In Tripura due to local problems the data collection was delayed.

[3] Because we do not have any information about women who have never been married, we can also not analyze child mortality rates of this group of women. We also do not have any indication how substantial fertility among never-married women is.

age 32 at the moment of the interview, who gave birth to at least 1 live born child since January 1993.[4] This reduces the sample to 25,196 women, who gave in total birth to 43,185 children born alive since January 1993. The data show that in rural areas around 92.6% of the pregnancies result in a live birth. In urban areas this percentage is somewhat lower, mainly due to more abortions. The percentage of stillbirths is higher in rural areas.

At the moment of the survey all qualified women are asked about their birth history. For each live born child the month of birth is recorded and whether or not the child is still alive at the moment of the interview. If a child died during the observation period, the age at which the child died is asked. The age of death is observed within intervals, in case a child died within a month after birth, the age of death is recorded in days, if the child died between 1 month and 2 years, it is recorded in months, and otherwise it is recorded in years. Because we are only interested in child mortality until age 5, we artificially right-censor at this age. Right-censoring can also occur if a child is alive at the moment of the interview and younger than 5 years old.

The data are recorded retrospectively and can therefore suffer from misreporting, for example a child who died at a very young age might not be reported. One may argue that this problem of misreporting becomes larger when the time interval between the moment of the interview and the date at which a child was born or died increases. If this is actually the case, we can get some indication of retrospective misreporting by comparing child mortality rates computed from the first wave of the NFHS conducted in 1992/1993, with those computed from the 1998/1999 wave. This is shown in Figure 1 and Figure 2 for rural and urban areas, respectively. In case there would be substantial retrospective misreporting the estimated mortality rates (in the overlapping period) based on the 1998/1999 wave should be much lower than those based on the 1992/1993 wave. As can be seen in the figures the mortality rates based on both waves are almost similar. Furthermore, it can be seen from the graphs that rural child mortality rates dropped somewhat during the 1990s, while urban child mortality rates remained constant. But still rural child mortality rates are much higher than urban child mortality rates.

Table 1 provides for each state (except Tipula) the number of women and the number of children in the sample, and neonatal (first month), infant (first year) and child (first 5 years) mortality rates. In rural India out of every 1,000 live

[4]The restriction to focus only on women below age 32 does not exclude many women from the sample, as recent fertility rates for older age-groups are very low.

born children almost 100 die before reaching age 5 and of these almost half die within the first month after birth (see also Kaplan-Meier estimates provided in Figure 3). The table shows that there is a large variation in child mortality rates across states. The ranking of the states by child mortality rates largely coincides with this ranking in 1960 (see Ravallion and Datt, 2002).

As mentioned above the survey consists of 3 questionnaires. This implies that we can distinguish 3 types of explanatory variables, child specific covariates, family specific covariates and village specific covariates. Table 2 gives the child specific characteristics. As can be seen slightly more boys are born than girls and during the first month boys have a higher probability of dying than girls. After 1 month, this changes and mortality rates of girls become higher, resulting that the under 5 years child mortality rate of girls is higher than that of boys. Most children are born when the mother is between 20 and 25 years old.[5] Child mortality rates decrease with the age of the mother at birth. Slightly above 1% of the children is part of a twin and these children have much high mortality rates than single born children. Finally, child mortality rates decrease with the length of the preceding birth interval.[6]

Table 3 provides information on family specific characteristics. In the rural areas hinduism is the dominating religion (even more than in the urban areas). Among hindu families child mortality rates are much higher than among families with other religions. Approximately one-third of the families belongs to a scheduled caste or tribe and one-third to other backward castes.[7] Child mortality in scheduled castes and tribes is higher than in other backward castes, where it is in turn higher than among families who do not belong to any backward caste. To some extent religion and castes are spatially correlated.

India is well-known for its high female illiteracy (e.g. Drèze and Sen, 1995). In our sample only one-third of the mothers finished primary school, while this is the case for slightly over half of the husbands. Child mortality rates are much higher in families with non-educated parents, which is particularly pronounced for the mother's education. Education is strongly correlated with the type of work. Education can therefore be considered as a measure for earnings capacity

[5]Because young women are more likely to be never married and thus do not enter the ever-married sample, the data might underreport the fraction of children born by young women.

[6]In the empirical analyses preceding birth interval will be treated as a continuous variable instead of a dummy variable.

[7]Other backward classes are castes and communities that have been designed by the government of India as socially and educationally backward and in need of protection from social injustice.

and consumption. A disadvantage of the NFHS is that it does not provide any information on household income or consumption expenditures. However, the NFHS is very rich on asset ownership, such as car, radio, television, refrigerator, etc. Asset ownership is a proxy for wealth and economic status (e.g. Filmer and Pritchett, 2001). In low-income countries, where household income is often difficult to measure (particularly in rural areas), consumption expenditures are often used in determining poverty (e.g. Deaton, 1997). Although asset ownership is less sensitive to short-term fluctuations than consumption expenditures, asset ownership and consumption expenditures are strongly correlated. Additionally, the NFHS provides information on livestock and land ownership, which are indicators of both economic and social status of a household. Land ownership is also an indicator of income from agriculture.

Obviously housing characteristics are important in explaining differences in child mortality rates. Child mortality rates decrease with the quality of housing. Child mortality among families living a house built of high-quality material (Pucca) is lower than among families living house of low-quality material (Kachha). Child mortality decreases with the number of rooms in the house, is lower when a separate room is used for cooking and when the house has electricity and some type of toilet facility. Child mortality rates also drop with the number of family members per room in the house.

Piped water is usually considered as safer than other sources of drinking water. This is confirmed by our data, which show that child mortality rates are substantially lower in families that have access to piped water. Among the families with access to piped water, child mortality rates are not lower for families that purify water. For any other source of water, child mortality rates are lower among the families that purify water. Furthermore, child mortality is higher for families that need more than 5 minutes to get to the water source but beyond 5 minutes it does not increase with the time to get to the water source. Finally, child mortality is lower in families that use clean cooking fuel than in families that use wood, crop residues or dung cakes as cooking fuel. This latter holds for both families that have a separate kitchen in the house and families without a separate kitchen.

Finally, Table 4 provides information on the village specific characteristics. The mortality rates are lower in villages that are closer to a town, that are larger in terms of families living in the village, that have a primary school, drainage, doctor, and are closer to a health facility or hospital.

3 Model

In this section we present our model for describing infant and child mortality. We focus on children that are born alive and model their mortality probabilities until reaching age 5. We use duration models to specify these mortality probabilities (see Van den Berg, 2001, for a recent survey on duration models). The model specifies mortality rates very flexibly. We extend the commonly used specifications by allowing covariates to have different impacts on mortality at different ages of the child. The model has a random effects specification. In particular, we allow for two types of frailty, at the level of the household and at the level of the child. These two types of frailty can be correlated with each other. The relevant outcome measure is age at death measured in months. First, we discuss the specification of the child mortality rates, and we end this section with the specification of the frailty components.

3.1 Specification of child mortality rates

We observe J families, which are denoted by $j = 1, \ldots, J$. Family j has some family specific characteristics that are described by a vector z_j, which includes for example religion of the family, asset ownership, parental education and availability of sanitation. A parameter s_j describes the fixed effect of the state in which the family in living. Obviously, two families living in the same state have the same state fixed effect. Furthermore, we allow for additional heterogeneity v_j that describes unobserved family specific characteristics. Both observed and unobserved family specific characteristics do not vary over time. During the observation period in family j there are I_j children born. The data describe a so-called inflow sample. We allow children born in the same family to differ in both observed and unobserved characteristics. The observed child specific characteristics such as gender and birth order, are captured in a vector x_{ij}. Additionally, there is some component w_{ij} that accounts for child specific frailty. We assume that all covariates are exogenous, i.e. the joint distribution of v_j and w_{ij} does not depend on z_j, s_j and x_{ij}.

For a child we can distinguish two possible observations, (i) the child is observed to die during the observation period before reaching age 5, and (ii) the child reached its fifth birthday alive or is still alive at the end of the observation period. In the first case, we observe that child i of family j died in some age interval $(\underline{t}_{ij}, \overline{t}_{ij})$. In the second case, $\underline{t}_{ij}$ equals 60 months or the age of the child in months at the end of the observation period if the child did not reach its fifth birthday (and $\bar{t}_{ij} = \infty$). We introduce a dummy variable d_{ij} that takes value 1 if the individual died within the observation period (the first case) and the value 0 otherwise. All observations are thus artificially right-censored at age 5.

We define T_{ij} as the continuous random variable (with one month as the unit of time) that describes the age at which child i of family j dies. This stochastic variable can only take non-negative values. A common way to model these types of random variables is to specify the corresponding hazard rates $\theta_{ij}(t)$. In the context of child mortality, the hazard rate is often referred to as mortality rate (e.g. Ridder and Tunalı, 1999). The mortality rate at age t can be interpreted as the intensity at which a child dies at this age, given that the child survived until age t. The mortality rate $\theta_{ij}(t)$ of child i living in family j at age t is specified as

$$\begin{aligned}\theta_{ij}(t|z_j, x_{ij}, v_j, w_{ij}) = \; & \lambda(t) \exp\{I(t \leq 1)(z_j\gamma_1 + x_{ij}\beta_1) + I(1 < t \leq 12)(z_j\gamma_2 + x_{ij}\beta_2) \\ & + I(12 < t \leq 60)(z_j\gamma_3 + x_{ij}\beta_3) + s_j\}\, v_j w_{ij}\end{aligned}$$

The mortality rate can be decomposed into three parts. The first part $\lambda(t)$ is the baseline hazard that is similar for all children in all families. This baseline hazard captures age dependence. The second part is a regression function, where $I(\cdot)$ is the indicator function taking the value 1 if its argument is true and 0 otherwise. Both the family specific effects z_j and the child specific x_{ij} are allowed to have different impacts on the mortality rate at three different age intervals, (i) during the first month after birth, (ii) from the second month until the first birthday, and (iii) after the first year until reaching age 5. The impact of the state fixed effect s_j does not vary over the child's age. The third part $v_j w_{ij}$ accounts for the effect of unobserved heterogeneity on the mortality rate.

Empirical studies of child mortality usually do not allow the effects of socio-economic and environmental covariates to vary over the child's age. Guo and Rodriguez (1992) mention that covariate effects might be dependent on the age of the child, but they do not explicitly model it. In their application the covariate effects do not vary over the child's age. The identification of the model is straightforward. The mortality rates $\theta_{ij}(t)$ satisfy the mixed proportionality assumption and the time varying regressors $I(\cdot)z_j$ and $I(\cdot)x_{ij}$ change values exogenously. The frailty components are assumed to be mean one random effects, for which the joint distribution is independent of the regressors. These conditions ensure that the model is identified (e.g. Van den Berg, 2001).

There is a one-to-one relation between the hazard rate $\theta_{ij}(t)$ and the distribution function of T_{ij}. In duration analyses it is often more convenient to use 'survivor' functions. The survivor function denotes the probability that a child survives up to a particular age,

$$S(t|z_j, x_{ij}, v_j, w_{ij}) = \Pr(T_{ij} > t|z_j, x_{ij}, v_j, w_{ij}) = \exp\left(-\int_0^t \theta_{ij}(s|z_j, x_{ij}, v_j, w_{ij})ds\right)$$

This survivor function will be used for the policy experiments performed in Subsection 5.

To estimate the parameters of our model we use Maximum Likelihood. Maximum Likelihood estimation requires some additional assumptions concerning the distribution of the frailty components. Let $G(V, W)$ denote the joint distribution function of the frailty components. The loglikelihood function equals

$$\log \mathcal{L} = \sum_{j=1}^{J} \log \left\{ \int_v \left(\prod_{i=1}^{I_j} \int_w \left(S(\underline{t}_{ij}|z_j, x_{ij}, v, w) - d_{ij} S(\bar{t}_{ij}|z_j, x_{ij}, v, w) \right) dG(w|v) \right) dG(v) \right\}$$

where $G(v)$ is the marginal distribution function of the family specific frailty term and $G(w|v)$ is the conditional distribution of child specific frailty given the family frailty.

3.2 Specification of duration dependence and frailty

Before estimating we determine the parameterization of the baseline hazard and of the distribution of both frailty terms.

The baseline hazard $\lambda(t)$ describes how the mortality rate changes with the age of the child. This is parameterized as a piecewise constant function

$$\lambda(t) = \begin{cases} \exp(\lambda_1) & 0 < t \leq 1 \\ \exp(\lambda_{2-6}) & 1 < t \leq 6 \\ \exp(\lambda_{7-12}) & 6 < t \leq 12 \\ \exp(\lambda_{13-24}) & 12 < t \leq 24 \\ \exp(\lambda_{25-36}) & 24 < t \leq 36 \\ \exp(\lambda_{37-48}) & 36 < t \leq 48 \\ \exp(\lambda_{49-60}) & 48 < t \leq 60 \end{cases}$$

Both family specific and child specific frailty are modelled using distributions with discrete mass-points. Distributions with discrete mass-points are flexible and attractive from a computational point of view. Such a distribution also allows easily for dependency between the two frailty components. In this sense our framework extends Sastry (1997) who also includes two independent frailty terms, which both follow a gamma distribution.

The family specific component has the distribution

$$\Pr(V_j = v^k) = \frac{\exp(p_k)}{\sum_{k=1}^{K}\exp(p_k)} \qquad k = 1,\ldots,K$$

We normalize the probabilities by setting $p_K = 0$. The mass-point locations should all be positive, $v^k > 0$, and V_j should have mean one (a normalization necessary since the location of $\lambda(t)$ is unrestricted). Therefore, we specify

$$v^k = \exp(\mu_k) \qquad k = 1,\ldots,K-1$$

and

$$v^K = 1 + \sum_{k=1}^{K-1}\exp(p_k)(1-\exp(\mu_k))$$

The child specific frailty can be interrelated with the family specific frailty. We specify

$$\Pr(W_{ij} = w^{lk}|V_j = v^k) = \frac{\exp(q_{lk})}{1-\exp(q_{lk})} \qquad l = 1,\ldots,L_k; k = 1,\ldots,K$$

Again we normalize the probabilities by setting $q_{kL_k} = 0$ for all $k = 1,\ldots,K$. To ensure that all mass-point locations are positive and the conditional random variables $W_{ij}|V_j = v^k$ have mean one, we impose the following specification

$$w^{lk} = \exp(\eta_{lk}) \qquad l = 1,\ldots,L_k-1; k = 1,\ldots,K$$

and

$$w^{L_k k} = 1 + \sum_{l=1}^{L_k-1}\exp(q_{lk})(1-\exp(\eta_{lk})) \qquad k = 1,\ldots,K$$

The joint distribution of the frailty components is thus described by the sets of parameters p_k, μ_k, q_{lk} and η_{lk}, which are estimated along with the other parameters when optimizing the loglikelihood function.

4 Empirical results

In this section we discuss the estimation results. Since our model contains many parameters, we will only discuss policy relevant parameters. All parameter estimates are presented in Table 5. The model allowed for both child specific frailty and household specific frailty. However, we could not find any significant and substantial child specific frailty, i.e. when optimizing the loglikelihood function the mass-point locations converged to each other. Therefore, we excluded child specific frailty from the model. The family specific frailty has two points of support. 78% of the probability mass is assigned to a mass point that is almost 13 times higher than the other mass point. Allowing for a third mass point does not improve the estimation results.

The fixed effects for the states differ are significantly from each other, the p-value for a Wald-test for joint significance is less than 0.0001. This implies that after controlling for child, family and village specific effects, there are still significant differences in child mortality rates between states.

The pattern of the baseline hazard decreases over the age of the child, which implies that mortality rates decrease as a child gets older. However, this duration dependence is not the only source of age dependence, as observed child characteristics and the household's socio-economic and environmental characteristics are allowed to have different impact on the mortality rates at different ages of the child. Also this source of age dependence in mortality rates is significant, a Wald-test rejects the null hypothesis that these covariates effects do not change over the age of the child (the p-value of this test is almost 0). This implies that the commonly used specifications in empirical research of child mortality, which impose that observed characteristics have the same effect on the mortality rate at all ages of the child are not sufficiently flexible to capture all relevant changes in child mortality rates.

Socio-economic and environmental characteristics are particularly important in the first month after birth. For each child we can compute $\exp(z_j\hat{\gamma}_k + x_{ij}\hat{\beta}_k)$ for $k = 1, 2, 3$, and we can use these to compute the variance within the population of children. A large variance of $\exp(z_j\hat{\gamma}_k + x_{ij}\hat{\beta}_k)$ indicates that the covariates are relatively important in explaining mortality rates. The computed variances equal 0.039, 0.0073 and 0.0051, for $k = 1, 2, 3$ respectively. This variance is thus highest in the first month after birth and decreases afterwards, indicating that socio-economic and environmental characteristics become less important in explaining mortality rates as a child gets older.

The first set of parameter estimates summarized in Table 5 concerns child specific covariates. Within the first month after birth boys have higher mortality rates than girls, particularly if it is the first born child of a mother. After that the gender of the child does not affect its mortality rates, if the child is the first born of a mother. However, among children who are not the first born child girls are significantly more likely to die than boys. Cleason, Bos and Pathmanathan (1999) suggest that due to social norms families have preferences for sons, less money is spent on girls, girls are taken to hospital in a later stage of illness than boys and girls are taken to worse doctors. Reducing such gender discrimination might substantially reduce child mortality rates. A child is more likely to survive if the mother was between age 20 and 25 when the child was born than children whose mother was younger or older at the moment of birth. A longer preceding birth interval significantly reduces mortality rates.[8] The National Population Policy aims at delaying childbearing (of young couples) and increased spacing of children, both of which can be useful in reducing child mortality. Children that are part of a twin have much higher mortality rates that single born children, particularly during the first month after birth. After that the difference in mortality rates decreases, but remains substantial and significant. We have tried to separate between the first born of a twin and later born, but there is no difference.

Education of the parents is important. Child mortality at any age is lower in case the parents finished primary education. This effect is stronger for the mother than for the father. The effect of land, livestock and asset ownership on mortality rates is negligible. Only some of the covariates are significant, particularly on neonatal mortality rates, but quantitatively the variables are not very relevant.

Most of the covariates describing the source of drinking water do not have a significant effect on mortality rates, but jointly these covariates have significant impacts. Water purification decreases mortality rates when the source of drinking water is not piped water, but increases mortality rates in case the household has access to piped drinking water. Even though the latter increase is insignificant, it is counterintuitive as one expects water purification to decrease child mortality rates. To purify water most households in rural areas strain water by cloth. The empirical result thus implies that either straining water by cloth lowers the quality of the piped drinking water or that households that purify water have access to lower quality piped drinking water than households that do not purify. Mortality rates are lower within families with some type of toilet facility, and access to electricity. The use of clean cooking fuels and having a separate kitchen also reduces mortality rates. We return to this in the next subsection.

Medical facilities do not seem to be very important in reducing mortality rates, except whether or not there is a doctor available in the village. Having a doctor in the village reduces the mortality rates of children after their first birthday. Neonatal mortality rates are somewhat higher in large villages and in villages that are closer to the nearest town. After the first month these effects

[8] Interacting the length of the preceding birth interval with gender shows that the covariate effect of the preceding birth interval is similar for boys and for girls.

change.

Next we investigate the fit of the model. The model predictions on child mortality are based on the estimated survivor function for child i in family j

$$S(t|z_j, x_{ij}) = \sum_{k=1}^{K} \Pr(V_j = v^k) \sum_{l=1}^{L_k} \Pr(W_{ij} = w^{lk}|V_j = v^k) \exp\left(-\int_0^t \theta(s|z_j, x_{ij}, v^k, w^{lk})ds\right)$$

which we evaluate at $t = 1, 2, \ldots, 60$. We weight the individual survivor function with the sample weights to make them nationally representative for rural India. Obviously, the estimated mortality rates directly follow from the estimated survivor functions.[9] Figure 4 shows how the mortality rates predicted by our estimated model coincide with the observed data. It should be noted that the 95%-confidence interval around the model predictions is relatively tight, the model predictions are very precise. The mortality rates computed from the actual data always falls within the model's confidence interval, indicating that the model is sufficiently flexible to describe the data accurately. However, a good fit of the model does not guarantee that the parameter estimates are true partial effects, i.e. it might be that some covariates account for child, family or environmental characteristics that are not included in the model. Failing to correct for all relevant heterogeneity may lead to serious biases in the estimated partial effects. For the policy experiments performed in the next subsection it is crucial that the parameter estimates are actually the true partial effects. Therefore, we have investigated the sensitivity of the parameter estimates with respect to including additional regressors. Obviously, such sensitivity analysis can never fully guarantee that all relevant heterogeneity is included in the model.

As mentioned earlier, India experienced a period of economic growth during the 1990s. Therefore, we have tried to include a polynomial describing calendar time variation in the model. Such a time trend does not have a significant impact on mortality rates (all parameter estimates of the polynomial were close to zero). The decreasing trend in mortality rates during the 1990s can thus be explained by improvements in observed socio-economic and environmental characteristics during the 1990s. For example, the fraction of the population that is either illiterate or did not finish primary eduction is steadily decreasing. In the sample of ever married women, the fraction of women that is illiterate decreased from 72% in the 1992/1993 wave of the NFHS to 67% in the 1998/1999 wave. Also more households have access to electricity and safe water sources.

[9] We use the Delta method to construct standard errors around the predicted mortality rates.

Next, we tried to include additional observed heterogeneity to the model. The variables that we added to the model did not have any significant effect on mortality rates and did not change the covariate effects of the other variables. In particular we tried including additional variables describing asset ownership, house ownership, size of land ownership, type of work performed by the parents, additional variables describing the medical facilities in area around the village, and village-level variables such as the percentage of households with access to piped water, electricity, etc.

5 Policy experiments

In this section we discuss some policy experiments based on the estimated model. We are interested in two measures, infant and child mortality rates. Table 6 provides the effects on the policy experiments on the infant mortality rate and Table 7 provides these effects on the child mortality rate. Both tables gives the present the number of death averted as a result of the policy interventions discussed below. All parameters are treated as causal effects and behavioral changes within a household as response to the policy experiments are ignored. Lee, Rosenzweig and Pitt (1997) mention that this ceteris paribus assumption may be too strong. We provide the percentage of household affected by the policy. If available we also give the costs per household to actually implement the policy. This allows to compute the costs per death averted as a result of a policy interventions.

The number of lives saved per 1,000 live born children is based on the estimated survivor functions (see the previous subsection). We compute the estimated survivor function twice, first without any changes and second after changing the explanatory variables affected by the policy experiment. The difference between these survivor functions provides the increase in probability that a child survives until a given age. We use the sample weights to make these differences in survival probabilities nationally representative and use the Delta method for computing standard errors.

The information on costs of policy interventions are estimates supplied by a World Bank staff member in India and are presented in Hughes, Lvovsky and Dunleavy (2001). Unfortunately, only for a small number of policy interventions costs information is available. The costs describe the situation in 1998. Annual costs are computed as the sum of recurrent costs and a discounted annuity on capita over the lifetime of the installation. In this computation the average family within rural areas is set to 5.4 and the discount rate is set to 12%.

Source of drinking water In the first set of policy experiments we consider the source of drinking water. Unsafe drinking water is considered to be a major cause for diarrhea among children and yearly many children die from diarrhea (Jalan and Ravallion, 2003). In rural areas piped water is a safer source of drinking water than the alternatives. Around 74% of the rural households does not have access to piped water (either private or public). In the first policy experiment, we consider the case where the type of water is changed to piped water. The distance to the water source is unaffected and households do not change their water purification behavior. The reduction in neonatal, infant and child mortality rates due to this policy experiment is small and insignificant. This results coincides with Jalan and Ravallion (2003) argue that access to piped water alone is not a sufficient condition for improving the child's health status. Their empirical results based on propensity score matching methods show that access to piped water does not reduce the incidence of diarrhea of children in poor families. Also Ridder and Tunalı (1999) do not find any significant effect of having access to piped water on child mortality rates in Malaysia.

As can be seen from Table 5 water purification is not particularly useful if a family has access to piped water, water purification increases child mortality rates. Therefore, we modify the policy experiment such that all households quit purifying water after having access to piped water. This policy experiment affects 84% of the households in our sample, 10% of the households only quit purifying, 17% quit purifying and obtain access to piped water and 57% only gets access to piped water. The reduction in mortality rates is somewhat larger than in the previous policy experiments, out of every 1,000 live born almost 7 more children are expected to be alive at their fifth birthday. However, this number of death averted is not significant.

Next, we modify the policy experiment even more by giving each household access to private piped water. We maintain that household do not purify their piped water. Of all households in rural India only 11% has access to private piped water. Connecting a household to private piped water costs annually around 100 rupees if connecting is made from a public well or public piped water in the community. This is the case in 38% of the households. In the remaining 51% the connection to private piped water will cost approximately 210 rupees per year. This implies that the costs of implementing this policy is around 145 rupees per household annually (1 US dollar equals around 42 rupees). The birth rate in the rural areas is around 26.2 live born children per 1,000 individuals yearly. The mean household size in the rural areas equals 5.5. Per 1,000 live born children the average costs of providing private piped water is slightly over 1 million rupees.[10] The policy experiment shows that per 1000 live born children 10 additional children reach age 5 (and that all benefits from having private piped water occurs in the first year after birth).[11] The costs of providing all households with private piped water per saved live thus equals 95,900 rupees.

ectricit Slightly over 51% of the households in our sample have access to some type of electricity. Providing access to electricity to the other 49% of the households in our sample reduces neonatal mortality with 2.6 children, infant mortality with 4.0 children and child mortality with 5.5 children. The reduction in infant and child mortality are actually significant. Providing 1% of the households with access to electricity reduces child mortality with approximately 0.11, which is similar to providing private piped water to 1% of the households. Ridder and Tunalı (1999) find for Malaysia that having access to electricity reduces child mortality. And also Wang (2003) finds using a cross-country analysis of DHS data that access to electricity is important in reducing child mortality rates.

ot er education About 67% of all mothers has not finished primary school. A policy that would ensure that all mothers would actually finish primary education, could reduce child mortality rates significantly at any age of the child. The model predicts that infant mortality rates reduce from 73 death per 1,000 live born to less than 60 and the child mortality rates reduces from 99 to 76. These results confirm Strauss and Thomas (1995), who find that the education of the parents and in particular the mother is important for health outcomes of children. Educated mothers are usually healthier and give birth to healthier babies. They also provide a healthier environment to children and are more likely

[1] Since the birth rate euals 2. 2 live born children per 1,000 inhabitant, 1,000 children are born alive per 38,18 i ndividuals. These 38,18 i ndividuals live in around, 940 households. Supplying a single household of private piped water costs around 145 rupees, thus supplying these, 940 households costs around 1,00, 940 rupees.

[11]Recall that we rejected a model where covariate effects are similar over the child s age. However, this restriction on the model is often imposed in literature on child mortality. Therefore, it is interesting to see what would be the results of this policy experiment in such restricted model. The restricted model predicts that child mortality decreases with slightly over 11 children (out of every 1,000), which is close to the prediction of our model. However, it predicts that neonatal mortality (significantly) reduces with 5.4 children, which is more than twice a much as the 2.1 death averted predicted by our framework with age varying covariate effects.

to have more knowledge about care-taking. Also Pritchett and Summers (1996) argue that education is often mentioned as having a strong effect on reducing infant and child mortality. In India women have a low social status. Clearly this has a negative impact on the number of girls that attends school, which leads to high illiteracy levels among women. This is also expressed in the reason for never having attended school by women. Compared to men, women often have never attended school because education was not considered to be necessary or because they were required for household work or taking care of siblings.

Sanitation faci itie Of the households living in rural areas only 19% has some type of sanitation facility.[12] The annual costs of providing a household a private toilet is approximately 250 rupees. Having sanitation facilities significantly reduces the child mortality rates. This result is in agreement with Bhagrave (2003) who finds using data for Utter Pradesh that access to sanitation facilities significantly reduces infant mortality. Almost 11 children out of 1,000 live born children are saved if all households would have sanitation facilities. The costs per death averted of providing each household with a private toilet equals 131,340 rupees. This is almost 37% higher than when providing private piped water.

Cooking fue Most households use wood as the main cooking fuel, only about 9% of the households use clean cooking fuels. As mentioned in the previous subsection using clean cooking fuels reduces mortality rates at all ages of the child. Our policy experiment shows that if all households would switch to using clean cooking fuels, infant mortality rates reduce with almost 16 children per 1,000 and child mortality with about 26 children. These estimates are significant. Kerosene is considered to be a clean cooking fuel and shifting from a dirty cooking fuel to kerosene costs annually 419 rupees per household. This implies that per death averted before age 5 the costs of providing clean cooking fuels equals about 99,855 rupees.

Also the use of clean cooking fuels might cause air pollution if the cooking takes place in the living area of the house. Therefore, we also investigate an alternative policy experiment, where households not only switch to clean cooking fuels, but they also use a separate room as kitchen. Having a separate room as kitchen seems to be particularly relevant during the first year after birth. Infant

[12]Note that in our sample containing families with a recent child born, the percentage households with sanitation facilities euals 23%, which is sl ightly higher than the overall percentage in the rural areas.

mortality reduces with over 27 saved lives compared to almost 16 when only clean cooking fuels are used.

Doctor Around half of the households lives in a village, where a doctor is available permanently. In this policy experiment we investigate how child mortality is affected if there would be a doctor available in each village. As mentioned in the previous subsection, living in a village with a doctor does not affect infant mortality rates. This is also expressed in the policy experiment. A doctor in the village reduces child mortality rates after the first birthday. If all villages would have a doctor on average 3.4 children per 1,000 die less before reaching age 5.

A intervention So far we have investigated effects of single policy interventions. To get an idea to what extent infant and child mortality can be reduced by public policy, we perform a policy experiment where we consider all policy experiments mentioned above jointly. Around 99% of the households will be affected by this joint policy experiment. Neonatal mortality rates can be reduced from around 47 death per 1,000 live born children to 22, infant mortality rates drop from 73 to 28 and child mortality rates reduce from about 100 to 37 children. Clearly improvements in household's socio-economic and environmental characteristics can reduces the mortality rates at any age of the child by more than half.

6 Conclusions

In this paper we have developed a flexible parametric framework for analyzing infant and child mortality. This framework is based on widely used hazard rate models, which we have extended with two features. First, the model allows individual characteristics and household's socio-economic and environmental characteristics to have different impacts on infant and child mortality at different ages. Second, we allow for frailty at multiple levels, which can be correlated with each other. The first feature seems to be particularly relevant in describing infant and child mortality, child-specific and socio-economic and environmental characteristics have significantly different impacts on mortality rates at different ages of the child.

We have used the estimated model to perform a number of policy experiments. The results from the policy experiments should be interpreted with care, as the proposed policy interventions may cause behavioral changes within the household that are not taken into account in the model. The policy experiments show that infant and child mortality rates can be reduced substantially by improving the household's socio-economic and environmental characteristics. Our model predicts that a significant number of under 5 years deaths can be averted by providing access to electricity, improving the education of women, providing sanitation facilities and reducing indoor air pollution. In particular, reducing indoor air pollution and increasing the educational level of women might have substantial impacts on child mortality. Reducing indoor air pollution by providing clean cooking fuels to a household is relatively expensive, for example compared with providing a household with sanitation facilities or safe drinking water. From a costs-benefits point of view, providing access to safe drinking water is a slightly cheaper policy (per under 5 years death averted) than providing clean cooking fuels.

The National Population Policy was developed in 2000 to establish population stabilization and pays special attention to health and education of women and children. Our results confirm the assumption of this policy that infant and child mortality rates can be reduced by improving the education level of women. Another, element of the policy is that it induces women to start childbearing at later ages and increases the spacing between children. Our estimation results show that this policy reduces infant and child mortality rates. Population stabilization should be achieved because lower infant and child mortality rates are assumed to reduce fertility rates. The relation between infant and child mortality and fertility decisions is not investigated in this paper.

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Region	Women	Children	Mortality ≤ 1	Mortality ≤ 12	Mortality $\leq$ 0
India	25, 19	43, 185	47.2	73.3	99.9
North					
Delhi	79	144	34.5	42.5	42.5
Haryana	872	1, 4 7	3. 9	1.9	7 .
Himachal Pradesh	783	1, 293	27.0	38.	47.
Jammu & Kasmir	822	1, 489	40.7	1.0	7 .1
Punjab	78	1, 14	3. 3	4.8	83.1
Rajasthan	2, 323	4, 13	52.	83.	115.2
Central					
Madhya Pradesh	2, 272	4, 122	5.0	102.7	158.8
Uttar Pradesh	3, 333	, 032	57.5	93.9	128.3
East					
Bihar	2, 738	4, 52	50.4	74.8	100.8
Orissa	1, 437	2, 30	49.3	83.9	107.1
West Bengal	95	1, 479	35.7	52.5	71.8
Northeast					
Aranachal Pradesh	487	841	31.3	50.7	84.5
Assam	1, 109	1, 823	35.5	2.2	82.8
Manipur	375	78	23.	4 .8	77.
Meghalaya	412	825	59.	100.9	131.4
Mizoram	200	392	28.9	1.2	74.
Nagaland	29	10	27.	44.4	80.4
Sikkim	407	33	31.3	51.4	73.1
West					
Goa	200	288	27.5	34.	41.3
Gujarat	818	1, 425	47.0	72.1	81.3
Maharashtra	871	1, 515	38.2	52.	8.0
South					
Andhra Pradesh	1, 057	1, 589	42.4	7.9	88.3
Karnataka	1, 110	1, 888	41.5	58.9	77.1
Kerala	29	912	11.9	15.	17.0
Tamil Nadu	923	1, 401	37.3	47.	71.9

Explanatory note: Women provides the number of women in the sample with at least 1 child born since January 1993. Children is the total number of live born children. The mortality rates are per 1,000 live born children, the number of children that die within 1 month, within 1 year, and before reaching age 5.

Table 1: Cumulative child mortality rates stratified by state.

	Share	Mortality		
		≤ 1	≤ 12	$\leq$ 0
Child characteristics				
Girl	0.48	44.9	72.8	10. 7
Boy	0.52	49.3	73.8	93.5
Age mother at birth -19 years	0.29	0.7	91.7	117.0
Age mother at birth 20–25 years	0.55	42.3	5.3	92.5
Age mother at birth 2+ years	0.1	35.2	2.2	89.9
Part of twin	0.01	254.7	331.4	34. 3
Single birth	0.99	44.5	70.0	9. 4
Preceding birth interval < 2 years	0.25	5.3	103.2	147.5
Preceding birth interval 2+ years	0.43	30.9	50.5	71.
First born and girl	0.15	47.1	72.7	92.0
First born and boy	0.17	3.4	88.8	104.4

Explanatory note: Share is the fraction of children that has a particular characteristic. Mortality gives the mortality rates per 1,000 live born children within the specified age (in months).

Table 2: Child mortality rates stratified by child specific characteristics.

	Share	Mortality		
		≤ 1	≤ 12	$\leq$ 0
Family background characteristics				
Hinduism	0.78	49.1	7 .5	103.5
Muslim	0.12	38.1	0.0	83.
Other religion	0.10	37.0	5. 0	81.4
Scheduled caste/tribe	0.35	53.9	84.3	121.2
Other backward caste	0.30	49.1	7 .5	98.
No backward caste	0.35	38.	59.3	79.7
Mother and husband				
Mother finished primary school	0.33	32.3	45.	57.0
Mother did not finish primary school	0. 7	53.3	84.	11. 8
Mother separated / widowed	0.02	1.8	104.1	130.3
Married but husband staying elsewhere	0.07	41.0	3.5	85.4
Husband living in household	0.91	47.3	73.4	100.2
Husband finished primary school	0.58	41.3	2.1	81.1
Husband did not finish primary school	0.42	54.3	8. 9	121.8
Land ownership				
No irrigated land	0.59	45.7	71.7	101.3
Irrigated land 0–1 acre	0.15	53.0	82.0	103.8
Irrigated land 1–5 acres	0.18	48.0	72.3	97.0
Irrigated land 5+ acres	0.08	43.4	9.2	8. 0
No non-irrigated land	0.35	44.9	72.	105.2
Non-irrigated land 0–1 acre	0.42	49.2	74.7	97.
Non-irrigated land 1–5 acres	0.1	47.4	71.	94.5
Non-irrigated land 5+ acres	0.07	4 .	72.1	9.

Explanatory note: Share is the fraction of families that has a particular characteristic. Mortality gives the mortality rates per 1,000 live born children within the specified age (in months).

Table 3: Child mortality rates stratified by family specific characteristic.

		Mortality		
	Share	≤ 1	≤ 12	$\leq$ 0
Household assets				
Livestock	0. 7	49.5	7 .2	100.7
No livestock	0.33	43.0	8.0	98.3
Radio	0.35	41.7	59.7	80.
No Radio	0. 5	49.8	79.8	109.0
Television	0.23	38.4	53.7	5.4
No television	0.77	49.4	78.2	108.3
Refrigerator	0.04	20.8	33.	45.9
No refrigerator	0.9	48.0	74.5	101.4
Bicycle	0.45	47.0	71.0	93.7
No Bicycle	0.55	47.4	75.7	105.8
Motorcycle	0.07	30.5	42.9	53.8
No Motorcycle	0.93	48.3	75.4	103.0
Car and or tractor	0.04	44.	4.0	71.2
No car or tractor	0.9	47.3	73.7	100.9
Cot or bed	0.84	47.	74.8	100.0
No cot or bed	0.1	45.4	71.3	98.9
Clock or watch	0. 2	43.0	4.8	83.2
No clock or watch	0.38	53.0	85.0	121.9
Sewing machine	0.17	39.9	59.4	74.4
No sewing machine	0.83	48.3	75.4	103.7

Table 3: (Continued).

	Share	Mortality		
		≤ 1	≤ 12	$\leq$ 0
Housing characteristics				
House owner	0.95	47.	73.9	100.
No house owner	0.05	38.	0.5	83.3
Type of house: Pucca	0.19	37.3	54.8	. 0
Type of house: Semi-Pucca	0.41	47.7	73.2	103.2
Type of house: Kachha	0.40	50.4	80.3	109.1
1 room in house	0.24	50.4	8. 7	122.
2 rooms in house	0.30	49.1	74.	104.8
3 rooms in house	0.18	45.4	8.1	91.2
4 rooms in house	0.12	4 .9	. 8	82.0
5 or more rooms in house	0.1	38.3	53.8	4.5
–2 members per room	0.35	5. 4	82.9	107.3
2–4 members per room	0.42	48.	74.9	102.5
4– members per room	0.1	3. 0	1.1	88.1
+ members per room	0.07	35.9	2.4	88.9
Kitchen and cooking fuels				
Separate room as kitchen and clean cooking fuels	0.07	24.0	34.9	45.0
Separate room as kitchen and no clean cooking fuels	0.42	43.9	4.7	82.0
No separate room as kitchen and clean cooking fuels	0.03	39.5	59.7	78.2
No separate room as kitchen and no clean cooking fuels	0.49	52.1	83.7	118.1
Toilet facility				
Flush toilet / Fit toilet / laterine	0.23	30.5	44.1	55.1
No facility	0.77	50.3	78.9	108.4
Electricity supply				
Irregularly supply	0.28	44.8	. 3	88.4
Regularly supply	0.23	37.8	5. 7	71.9
No supply	0.49	51.	82.3	114.7

Table 3: (Continued).

		Mortality		
	Share	≤ 1	≤ 12	$\leq$ 0
Water source				
Piped water (private)	0.11	40.8	55.0	73.0
Piped water (public)	0.15	3. 5	57.9	82.2
Handpump water (private)	0.17	47.9	71.4	94.3
Handpump water (public)	0.25	52.3	82.9	114.3
Well water	0.24	49.7	78.8	104.9
Other	0.07	39.4	9.7	104.
Purifies piped water	0.10	41.4	1.0	82.
Does not purify piped water	0.1	3. 3	54.3	7 .5
Purifies handpump water	0.0	52.8	7 .3	101.1
Does not purify handpump water	0.37	50.2	78.3	10. 7
Purifies well water	0.08	39.5	4.0	83.1
Does not purify well water	0.1	54.3	85.7	115.0
Purifies other water source	0.03	33.2	5.	95.9
Does not purify other water source	0.04	43.1	72.1	109.9
Time to get to water source				
–5 minutes	0.52	45.	7.2	89.8
5–10 minutes	0.1	47.	79.3	108.5
10–20 minutes	0.15	50.7	79.4	110.7
20–30 minutes	0.11	47.8	78.9	109.5
30+ minutes	0.0	50.	87.9	112.9

Table 3: (Continued).

		Mortality		
	Share	≤ 1	≤ 12	$\leq$ 0
Village characteristics				
Nearest town –10 km	0.49	44.3	71.4	99.3
Nearest town 10–25 km	0.35	48.9	72.1	9. 0
Nearest town 25+ km	0.15	52.9	83.0	111.7
–250 families in village	0.44	49.	79.	110.3
250–1000 families in village	0.42	4 .1	71.0	95.9
1000+ families in village	0.14	44.2	4.5	85.1
Primary school in village	0.89	4 .2	72.1	98.4
No primary school in village	0.11	54.8	83.0	111.5
Drainage in village	0.45	45.5	71.9	97.
No drainage in village	0.55	48.7	74.	102.0
Health facility –5 km	0.7	45.0	8.9	93.1
Health facility 5–10 km	0.1	53.5	8. 1	117.5
Health facility 10+ km	0.08	5. 1	90.	130.1
Hospital –5 km	0.35	43.4	8.0	94.8
Hospital 5–10 km	0.24	48.	74.	99.4
Hospital 10+ km	0.41	49.7	77.3	104.8
Doctor available	0.50	45.9	70.1	92.7
No doctor available	0.50	48.	77.0	108.0

Explanatory note: Share is the fraction of families that has lives in a village with a particular characteristic. Mortality gives the mortality rates per 1,000 live born children within the specified age (in months).

Table 4: Child mortality rates stratified by village specific characteristic.

Unobserved heterogeneity		
p_1	-1.2	(0.47)
μ_1	-2.33	(1.49)
States		
Delhi	-0.12	(0.44)
Haryana	0.00	(0.15)
Himachal Pradesh	-0.22	(0.18)
Jammu & Kasmir	0.14	(0.1)
Punjab	0.19	(0.17)
Rajasthan	0.27	(0.12)
Madhya Pradesh	0.4	(0.11)
Uttar Pradesh	0.39	(0.11)
Bihar	0.092	(0.12)
Orissa	0.070	(0.13)
West Bengal	-0.34	(0.15)
Arunachal Pradesh	-0.14	(0.19)
Assam	0.024	(0.14)
Manipur	-0.027	(0.21)
Meghalaya	0.29	(0.18)
Mizoram	0.07	(0.25)
Nagaland	-0.20	(0.23)
Sikkim	-0.003	(0.21)
Goa	-0.49	(0.32)
Gujarat	0.11	(0.15)
Maharashtra	-0.070	(0.15)
Andhra Pradesh	0	
Karnataka	-0.079	(0.13)
Kerala	-1.11	(0.30)
Tamil Nadu	-0.32	(0.15)
Duration dependence		
λ_1	-1.54	(0.25)
λ_{2-6}	-3.41	(0.31)
λ_{7-12}	-3.98	(0.32)
λ_{13-24}	-4.31	(0.40)
λ_{25-36}	-4.72	(0.41)
λ_{37-48}	-4.98	(0.41)
λ_{49-6}	-5.0	(0.41)

Explanatory note: Standard errors in parentheses.

Table 5: Estimation results.

	$\text{age} \leq 1$		$1 < \text{age} \leq 12$		$12 < \text{age} \leq$ 0	
Child specific characteristics						
Being girl	−0.038	(0.059)	0.24	(0.077)	0.58	(0.098)
Age Mother at birth 20–25	−0.14	(0.055)	−0.17	(0.080)	−0.11	(0.095)
Age Mother at birth 2–32	−0.17	(0.085)	0.054	(0.11)	−0.032	(0.1)
Being part of twin	2.09	(0.083)	1.78	(0.1)	1.09	(0.29)
Preceding birth interval (in years)	−0.38	(0.027)	−0.35	(0.033)	−0.45	(0.051)
Being first child of mother and boy	−0.52	(0.090)	−0.7	(0.13)	−1.21	(0.18)
Being first child of mother and girl	−0.81	(0.095)	−1.01	(0.13)	−1. 8	(0.17)
Household specific characteristics						
Hinduism	0.25	(0.11)	−0.044	(0.15)	−0.03	(0.17)
Muslim	0.19	(0.14)	−0.15	(0.18)	−0.072	(0.23)
Scheduled caste/tribe	0.12	(0.04)	0.028	(0.089)	0.28	(0.12)
Other backward caste	0.13	(0.04)	0.07	(0.090)	−0.055	(0.13)
Mother and husband						
Mother finished at least primary school	−0.21	(0.05)	−0.41	(0.098)	−0.5	(0.15)
Mother separated	0.14	(0.1)	0.18	(0.21)	−0.058	(0.2)
Husband staying elsewhere	−0.10	(0.10)	−0.19	(0.1)	0.0	(0.18)
Husband finished at least primary school	−0.15	(0.053)	−0.15	(0.072)	−0.30	(0.094)
House characteristics						
Type of house: Pucca	0.053	(0.081)	−0.040	(0.12)	−0.17	(0.18)
Type of house: Semi-Pucca	−0.034	(0.05)	−0.11	(0.074)	0.14	(0.094)
2 rooms in house	−0.39	(0.070)	−0.	(0.092)	−0.55	(0.11)
3 rooms in house	−0.50	(0.08)	−0.88	(0.12)	−0.9	(0.1)
4 rooms in house	−0. 7	(0.10)	−1.07	(0.14)	−1.35	(0.20)
5 or more rooms in house	−0.85	(0.11)	−1.29	(0.1)	−1.54	(0.22)
2-4 members per room	−0.52	(0.055)	−0.57	(0.081)	−0.	(0.11)
4- members per room	−0.98	(0.081)	−1.10	(0.11)	−1.40	(0.15)
+ members per room	−1.24	(0.11)	−1.34	(0.15)	−1.53	(0.18)
Land ownership						
Irrigated land	0.099	(0.01)	−0.023	(0.083)	−0.070	(0.11)
Only non-irrigated land	0.02	(0.07)	−0.097	(0.093)	−0.00	(0.12)

Explanatory note: Covariate effects for different ages of children.

Table 5: (continued) Estimation results.

	age $\leq$ 1		1 $<$ age $\leq$ 12		12 $<$ age $\leq$ 0	
Household assets						
Livestock	0.11	(0.05)	0.05	(0.075)	−0.032	(0.097)
Radio or television	0.072	(0.05)	−0.15	(0.081)	0.23	(0.10)
Refrigerator	−0.27	(0.19)	−0.11	(0.30)	0.092	(0.45)
Car and or tractor	0.13	(0.14)	0.20	(0.20)	−0.34	(0.38)
Cot or bed	−0.1	(0.0)	−0.030	(0.092)	0.12	(0.12)
Clock or watch	0.037	(0.055)	0.13	(0.074)	−0.18	(0.09)
Water source						
Piped water (private)	0.084	(0.15)	−0.59	(0.22)	−0.13	(0.2)
Piped water (public) $<$ 10 min	0.10	(0.15)	−0.34	(0.20)	−0.28	(0.2)
Piped water (public) $>$ 10 min	−0.07	(0.15)	−0.12	(0.20)	0.0021	(0.24)
Handpump water (private)	0.15	(0.13)	−0.2	(0.17)	−0.18	(0.21)
Handpump water (public) $<$ 10 min	0.14	(0.13)	−0.094	(0.1)	−0.11	(0.20)
Handpump water (public) $>$ 10 min	0.14	(0.13)	−0.17	(0.17)	−0.040	(0.20)
Well water $<$ 10 min	0.1	(0.13)	−0.13	(0.1)	−0.1	(0.20)
Well water $>$ 10 min	0.2	(0.13)	−0.015	(0.17)	−0.070	(0.20)
Other water source $<$ 10 min	−0.14	(0.20)	−0.14	(0.24)	−0.083	(0.31)
Other water source $>$ 10 min	0		0		0	
Household purifies water						
Piped water	0.11	(0.11)	0.23	(0.1)	0.091	(0.20)
Nonpiped water	−0.07	(0.070)	−0.070	(0.094)	−0.091	(0.12)
Toilet facility						
Flush toilet / Fit toilet / laterine	−0.13	(0.080)	−0.07	(0.11)	−0.24	(0.15)

Table 5: (continued) Estimation results.

	age $\leq$ 1		$1 <$ age ≤ 12		$12 <$ age $\leq$ 0	
Electricity supply						
Electricity available	−0.10	(0.057)	−0.094	(0.079)	−0.11	(0.10)
Kitchen and cooking fuels						
No separate kitchen & clean fuel	−0.018	(0.15)	−0.43	(0.27)	−0.81	(0.41)
Separate kitchen & clean fuel	−0.45	(0.15)	−0. 5	(0.28)	−0.42	(0.37)
Separate kitchen & dirty fuel	−0.0038	(0.05)	−0.008	(0.079)	−0.22	(0.11)
Village characteristics						
Drainage in village	−0.02	(0.051)	0.12	(0.09)	0.022	(0.094)
Doctor available	0.0000	(0.050)	−0.0030	(0.09)	−0.27	(0.091)
Health facility 5+ km	0.087	(0.054)	0.028	(0.074)	0.08	(0.099)
Hospital 10+ km	−0.057	(0.051)	0.0090	(0.073)	−0.097	(0.095)
Nearest town 10–25 km	0.11	(0.053)	−0.14	(0.077)	−0.19	(0.10)
Nearest town 25+ km	0.13	(0.070)	−0.028	(0.09)	−0.10	(0.12)
$<$ 250 families in village	−0.18	(0.082)	0.11	(0.12)	−0.034	(0.1)
250–1000 families in village	−0.12	(0.07)	0.02	(0.12)	−0.11	(0.15)
Primary school in village	−0.080	(0.071)	−0.038	(0.10)	0.090	(0.13)

Explanatory note: Standard errors in parentheses.

Table 5: (continued) Estimation results.

	Current level of access	Under 1 year death averted (per 1,000 birth) from reaching 100% access	Costs per life saved
Access to piped water	2%	4.0 (3.5)	
Access to piped water & no purification	1%	.1 (3.8)	
Access to private piped water & no purification	%	10.9 (5.1)	$92,380$
Access to electricity	51%	4.0 (2.0)	
Mother finished primary school	33%	13.7 (2.5)	
Has toilet facility	23%	.1 (3.8)	$230,373$
Uses clean cooking fuel	9%	15.7 (5.)	$15,943$
Has separate kitchen & uses clean cooking fuel	7%	27.3 (5.7)	
Doctor available in village	50%	0.0 (1.4)	
Access to all of the above	1%	45.2 (4.4)	

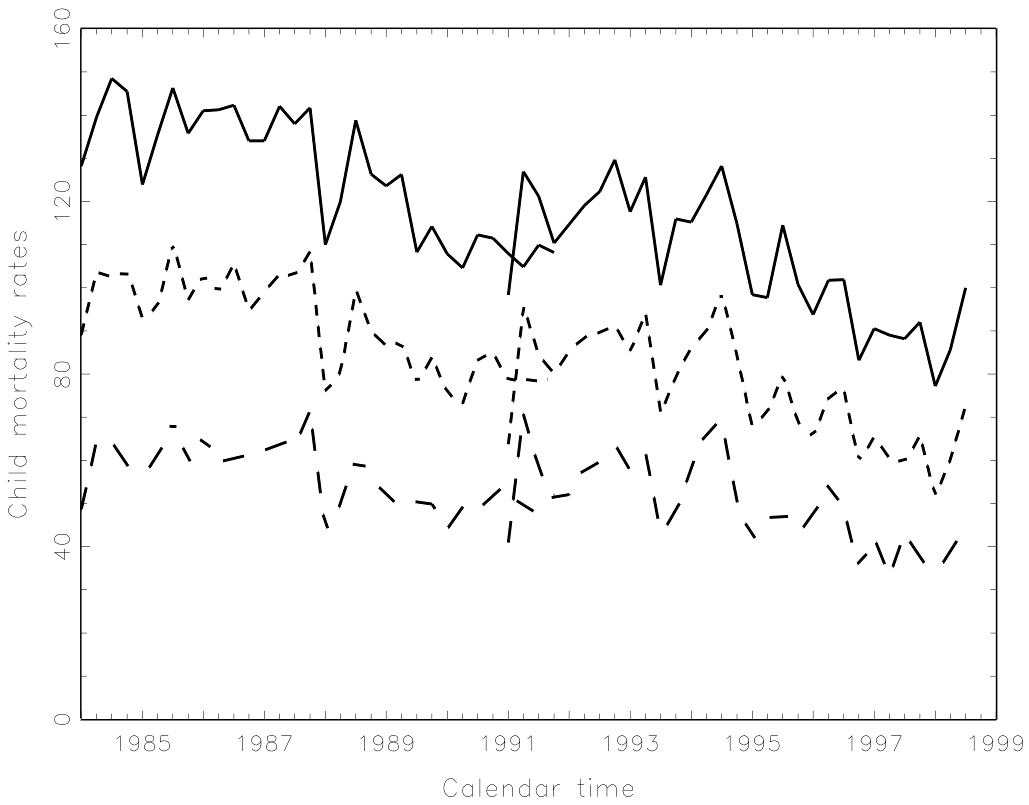
Explanatory note: Clean cooking fuels are kerosine. The annual costs of providing access to piped water is 145 rupees, the annual costs of providing toilet facilities is approximately 250 rupees and the annual costs of providing clean cooking fuels is 419 rupees per household.

Table 6: Reduction in infant (under 1 year) mortality rates from policy changes: achieving universal access to basic services in rural India (standard errors in parentheses).

	Current level of access	Under 5 years death averted (per 1000 birth) from reaching 100% access	Costs per life saved (in rupees)
Access to piped water	2% (4.)	4.4	
Access to piped water & no purification	1% (5.1)	.8	
Access to private piped water & no purification	% (7.0)	10.4	9,821
Access to electricity	51% (2.)	5.5	
Mother finished primary school	33% (3.3)	22.9	
Has toilet facility	23% (4.9)	10.7	131,334
Uses clean cooking fuel	9% (. 9)	2. 5	99,849
Has separate kitchen & uses clean cooking fuel	7% (9.2)	33.	
Doctor available in village	50% (1.8)	3.4	
Access to all of the above	1% (5.8)	2.8	

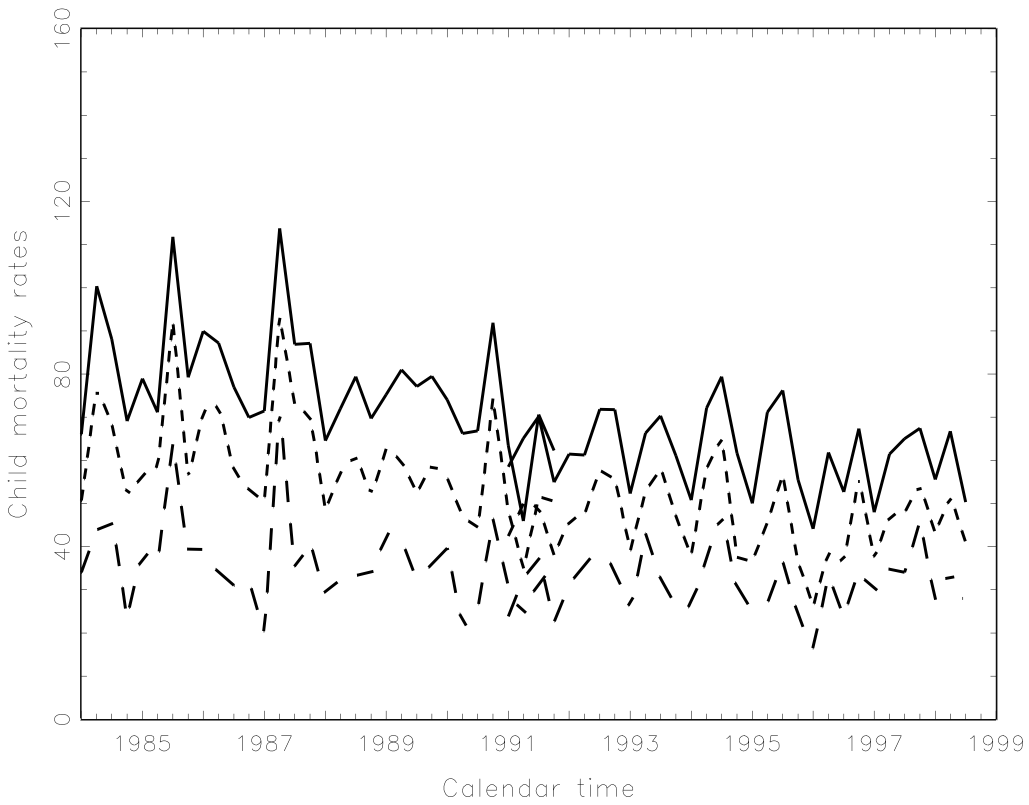
Explanatory note: Clean cooking fuels are kerosine. The annual costs of providing access to piped water is 145 rupees, the annual costs of providing toilet facilities is approximately 250 rupees and the annual costs of providing clean cooking fuels is 419 rupees per household.

Table 7: Reduction in infant (under 5 years) mortality rates from policy changes: achieving universal access to basic services in rural India (standard errors in parentheses).



Explanatory note: The lower line is the mortality rate in the first month after birth, the middle line the mortality rate during the first year after birth and the upper line the mortality rate during the first 5 years after birth. The left-hand side of the figure is based on the 1992 wave of the NFHS, the right hand side on the 1998/1999 wave. For 1991 measures using both surveys are available.

Figure 1: Rural child mortality rates over calendar time.



Explanatory note: The lower line is the mortality rate in the first month after birth, the middle line the mortality rate during the first year after birth and the upper line the mortality rate during the first 5 years after birth. The left-hand side of the figure is based on the 1992 wave of the NFHS, the right hand side on the 1998/1999 wave. For 1991 measures using both surveys are available.

Figure 2: Urban child mortality rates over calendar time.

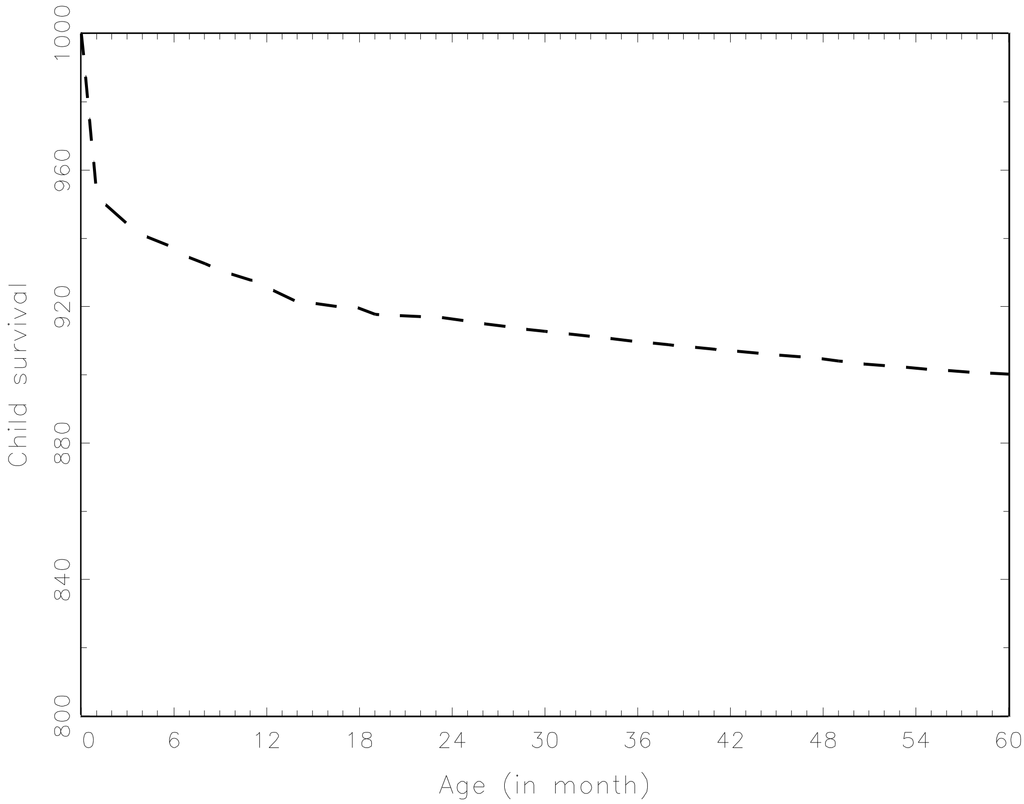


Figure 3: Kaplan-Meier estimates for the survival of 1,000 live born children.

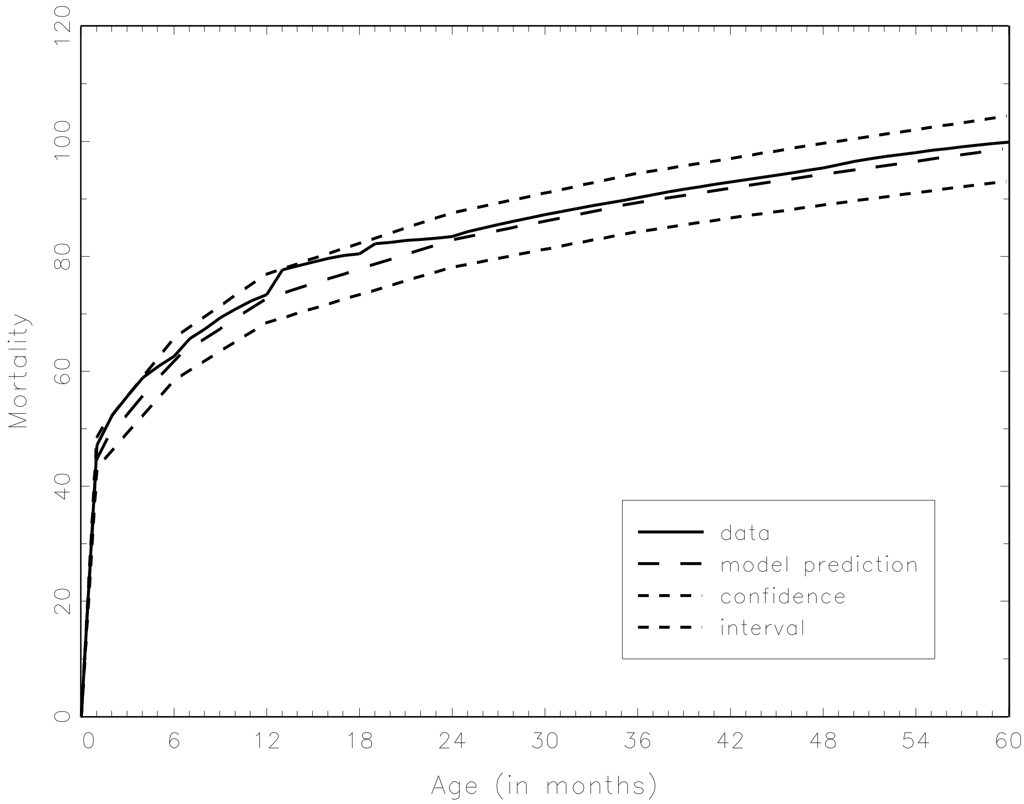


Figure 4: Size of child mortality before a particular age (out of 1,000 live born). Both the data and the model predictions are weighted to make them representable.